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USE OF SECONDARY METHODS OF OIL PRODUCTION IN AZERBAYDZHAN OIL FIELDS

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METHODS IN THE AZNEFT' [AZERBAYDZHAN OIL FIELDS]

The task assigned the oil industry by the Five-Year Plan for reconstruction and development of the USSR national economy is to increase oil production by all available means. Beside exploration and development of new petroleum deposits and horizons, a more complete extraction from the oil deposits already exploited in the Apsheron Peninsula is necessary.

As we know, continuous expenditure of a bed's resources brings about a sharp decrease in yield, which is sometimes erroneously attributed to the bed's exhaustion. Actually, more than half of the oil still remains underground. This residual oil is reliable reserve, and must be extracted by secondary recovery methods. The Five-Year Plan stresses the great importance and the necessity for their extensive development, of secondary recovery methods.

The Azneft' combine planned a great amount of work for 1947, providing for air compression in the beds and for various types of flooding.

Air Compression in the Beds (Mariette Method)

Application of the Mariette method to horizon V of the Stalinneft' field, interrupted for a considerable period during the war, was resumed in February 1947.

Five wells were chosen for air injection. With 20 other wells they formed four groups. As operations were begun but recently, preliminary

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50X1-HUM

conclusions on the efficiency of air compression are availabe for one group only (well No 1186), on the basis of operations covering more than 4 months.

Table I gives an approximation of the results:

Table I. Average Yield per 24 Hours (%)

Well No	January 1947 (before the Process)		May 1947	
	Oil	Water	Oil	Water
937	100	160	230	280
880	100	32	210	267
874	100		80	
1098	dry		oil	
	100		200	

After 4 months of exploitation, the yield of these four wells was doubled.

At the beginning of the operation, the amount of air pumped per 24 hours was 700 cubic meters. In April 1948, this amount was increased to 1,400 cubic meters. At this time, a break-through of air occurred in well No 880. This was disclosed by an increase of nitrogen to 50 percent in the gas outside the pipes. In May the nitrogen content, which reached 70 percent necessitated a slowdown in air pumping.

It is interesting to point out that the maximum increase of oil yield was obtained from Well No 880 where the air content in the gas outside the pipes was also the largest. In the three other wells the presence of such air was not observed.

In the oil fields of Leninneft' (Lenin Oil Field Combine) the Mariette method is applied to horizon II in a pericline of the Romany fold. Three wells are used for air injection: No 997, 1602, and 1202. As pumping in the last two has been started but recently (end of April 1947), it is premature to speak of results for the respective groups.

In the first group (well No 997), operations started in December 1945 and since then 433,000 cubic meters of air were forced into the layer. The yield of oil from the wells surrounding well No 997 increased by 34 percent (Table 2).

Table 2. Average Yield Per 24 Hours (%)

Well No	Before the Process		May 1947	
	Oil	Water	Oil	Water
761	100	65	130	74
995	100	380	200	730
1204	100	-	130	-
	100		134	

50X1-HUM

It is interesting to note that in two other wells, each separated from the injection well by one well (beyond the wells cited in the table above) the results of the injection were not felt at all, i.e., the yield of these wells did not increase.

In Kirovneft' (Kirov Oil Field) the Mariette method was applied in the southeastern part of the deposit. Its surface is approximately 50 hectares and the slope varies from 15 to 20 degrees. Exploitation of the site began in 1917. Because of a classification existing then, the PK formation was erroneoulsy included in the so-called Nizhnekirmakinsk lower formation of KKG. Thus a series of wells simultaneously exploit both horizons PK and KS_6.

The KS_6 horizon is composed of fine-grained sands and of alternate layers of clay and sandstone, while the sand grains of the PK horizon are medium or large and its clay and sandstone interlayers are spaced widely apart. The oil is heavy, its specific gravity being 0.920, and has a considerable tar content.

All the wells are exploited with deep-well pumps and form four groups corresponding to the number of injection wells.

Some of the wells produce oil without water. In others some infiltration of top water is observed. The water content does not exceed 10 percent of all the liquid extracted.

Air was forced into the bed, starting May-August 1946, through four air-injection wells reacting on 17 wells equipped with deep-well pumps. An 18 percent increase in production resulted in the sector.

The Oil Trust is now completing a technological study of the Mariette method. The study covers the upper part of the Sulu-Tepinsk field comprising about 100 low-yield wells.

In the Artemnef' (Artem Oil Combine) the Mariette method was applied to 33 hectares in the eastern wall of the northern anticline. The sector is bordered on the south by the major fault, and on the southeast by the limit of the oil-bearing area. The PK formation is the only one whose thickness varies considerably, decreasing progressively toward the east. In the sector where operations are in progress, the thickness is one half of that found on the southwestern wall. Lithologic composition also varies toward the east. It is characterized by the appearance of argillaceous interstices, and various kinds of fine-grained sands.

A comparison of the granular composition of PK sands on both walls of the structure shows a decrease of coarse-grainedness and a considerable increase in argillaceous particles on the eastern wall. The sands of this wall are more silty than in the western part of the structure.

The development of this sector was slow, covering a period of 10 years. The first well was drilled in 1930, the last wells in 1940. The initial output in this part of the field was far below the first results obtained in the western part of the structure.

All the wells are equipped with deep-well pumps. Dynamic levels are very low. They are often found at the top filter openings. The sector subject to depression was divided in four groups.

Air pumping started in August 1945, operating through wells 180 and 189; then wells No 363 and 195 were added in March and July 1946.

50X1-HUM [redacted]

Up to March 1947, 4.5 million cubic meters of air were pumped through the four wells in the PK formation. The volume of air forced into the layer was increased from 4,000 to 27,000 cubic meters per 24 hours. No increase of production was observed during the operation. This failure, however, was not carefully analyzed, at first, but later studies revealed that a break-through, which had occurred almost at the start of the process, was the main reason for the operation's inefficiency.

The by-pass was not discovered in time because the air content in the gas outside the pipes was being measured by the amount of oxygen, the lack of which was erroneously considered an indication of normal operation. Meanwhile the oxygen of the air, when passing through the bed, was almost completely absorbed by oil. The existence of a break-through was established only this year, by measuring the nitrogen content.

As one can judge from the foregoing data, in the Azneft' oil fields the method of forcing air into the bed gave positive results most of the time. The solution of the main problems of its utilization results in a considerable increase in the possible number of oil wells, and a complete coverage of the oil-bearing area of the bed.

FLOODING METHODS

Transcontour Flooding

Slow movement of contour water is observed only in Romany, the extreme eastern part of the widespread oil-bearing PK formation of the Leninneft'. The decision was made to flood the area surrounding the bed to increase the pressure in the bed, and to accelerate the water inflow. For technical reasons, wells in the vicinity of the present boundary of the oil-bearing area could not be used for injection. It was therefore necessary to pump water into wells located lower on the declivity of the strata (No 1583, 1582, 1574, 1578, and 1585).

Notwithstanding the late start in operations, the level of liquid rose 45 meters in well No 5175 (inactive) between the limit of the oil-bearing area and the injection well which had been prepared for observations. No rise, however, was observed in a well which was below the injection well on the declivity. The injected water was therefore directed toward the petroleum deposit.

It is necessary to point out that for experimental purposes the water underwent no special processing. It was merely freed from physical impurities by settling. In this connection, the absorbing power of one of the injection wells started to decrease and water had to forced in under a pressure o 7 to atmospheres. In the meantime, water was absorbed without pressure by the other wells.

Buzovny ...t' Trust

The Mashtagin petroleum area is in the northeastern part of the Apsheron Peninsula. It forms a branch of the Fat'mai-Balkhan fold and extends to the sourtheast in the form of a wide pericline. An undulation of the axis of this branch forms, a little further, the Buzovny upheaval. The main characteristic of this latter formation is the vagueness of the productive layers' shape in the upper part of the horizon, while further down there are strong d... type dislocations. Since both structures are separated only by a sha..., anticline, the oil-bearing strata in the lower part of the productive horizons are uninterrupted. The method of transcontour flooding was applied i- the PK formation.

50X1-HUM

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The oil deposit parallels the southern wall of the structure, bordering a fault which extends in a latitudinal direction. After 2 years of operations the pressure in the bed decreased 30 atmospheres. The structure of the PK formation is not established. The oil is heavy, its specific gravity being 0.920. During the early working stage a gas cover was not discovered. Nevertheless, the oil was assumed to be fully saturated with gas since the lowering of the bed's pressure by the first wells provoked a sharp increase and fluctuation in gas pressure and other manifestations, followed by an emission of pure gas in wells No 80, 81, 108, etc., in the upper part of the deposit near the fault. In order to apply the method of transcontour flooding it was necessary to establish the extent to which the water-bearing and oil-bearing parts of the PK were in contact. If there is no contact, flooding will obviously be of no use.

Since the thickness of the PK formation is considerable, it was important to determine which part of the layer the water should be pumped into. Theoretical and practical considerations suggested introducing the water near the bottom of the bed. It is necessary to note that according to core-sampling data, the PK formation within the limits of the Mashtagi-Buzovny deposits is subdivided into three parts. The collecting capacities of these three parts, PK_1, PK_2, and PK_3, are quite different.

Numerous analyses show that in the lower part of the PK formation porosity and permeability of sands decrease depending on their carbonate content. Continuous core-sampling was conducted throughout the whole thickness of the PK formation by means of well No 217 drilled for this purpose and through well No 121 drilled previously. This sampling shows for each part of the formation the content of $CaCO_3$ (in percent):

Well No 217		Well No 121	
PK_1	6.9	PK_1	7.4
PK_2	11.7	PK_2	12.1
PK_3	18.7	PK_3	22.3

Therefore two wells, about 1 kilometers distant from each other, provide very similar data, which show the carbonate content increasing almost three times in the lower part of the formation.

If it is supposed that the basic mass of the calcareous salts were deposited in the form of a cement in the porous spaces, it is obvious that both porosity and permeability will decrease when the amount of calcareous cement is increased. Different samples of sandstone, obtained from the lower parts of the formation, show that a 40 percent increase in carbonate content causes a decrease in porosity down to 3.5 percent, and a considerable decrease in permeability.

Data gathered from exploitation of wells confirmed the statements above. The conditions of the PK_3 formation are such that exploitation is hardly practicable. Therefore, all the oil wells exploit only formation PK_1 and PK_3.

Investigations planned should establish the degree of contact between the water-bearing and oil-bearing parts of the bed, and should solve the problem of where to pump the water; whether into the PK_3 or separately into the PK_2 and PK_3. Well No 217 was drilled for this purpose and for finding the bed's absorption capacity. After the studies are completed, this well may be used for injection purposes.

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Since information on the movement of contour water is essential for successful results, to start transcontour flooding without pertinent information may seem to be an uncertain enterprise. However, sufficient time cannot be spared for a precise study of formation conditions because of the sharp decrease of pressure in the bed. Bearing in mind the correlation existing between the contours of formations PK and KS, one must realize that immediate flooding is a technically justified risk.

The contours of the upper horizons of the Kirmakinsk formation are more extensive than the contours of the PK formation. For this reason, injection wells located beyond the oil-bearing limits of the PK will be within the oil-bearing limits of the KS formation. In case of negative results, therefore, water-injection wells striking the PK formations's water-bearing part may be used as oil wells upon the resumption of oil exploitation in the KS horizons.

Field Flooding

Field flooding, the most effective method of flooding, is entitled to special attention. A geological technical project to flood the PK 4 and 5 formation of the Khorasan field has already been started, as one of a series of work projects for 1948.

The minimum depth of the PK formation (about 300 meters) is found in the western part, highest, of the Khorasan fold. The beds have a 22 degree slope and the specific gravity of the oil is 0.932.

The peculiar aspect of this area's development is that in the past the fear of uncovering the underlying water interrupted drilling in the upper part of the formation and, therefore, wells did not penetrate more than 5-10 meters into the bed. Analysis of oil exploitation revealed that the amount of oil extracted from the PK_1 formation was greater than the amount that would be found within its oil-bearing limits. Therefore, the lower strata were worked during the exploitation of PK_1. Lack of underlying water and oil saturation through the whole thickness of the formation were ascertained later by separate borings through the untouched lower PK formations. Such a method of exploitation facilitated the removal of gas, and the retention of a considerable amount of the oil in the lower part of the PK formation.

Calculations show that the current coefficient of utilization of pore space does not exceed 0.05-0.10.

Plans were made for an efficient flooding to be started this year. To this end, the groundwork for drilling a group of five wells was started.

Contour Flooding

This type of flooding is recommended by the author only for beds under gas pressure. The analysis of exploitation in the Apsheron peninsula shows that there are a number of oil-bearing horizons with large reserves. Transcontour flooding is not applicable there because of the physical and geological properties of these horizons. After a lengthy period of operations, no movement of contour water was observed in these horizons. Oil was brought into the wells only by the expansive energy of gas dissolved in it.

The PK formation presents all the characteristics of a horizon under gas pressure. Lengthy exploitation and a considerable decrease of pressure in the bed brought about no change in the water-oil contact.

The above statements are illustrated by the profile throught the northern old of Artem insland, where data on static levels show a depression developing during operations above the oil deposit. Along the boundaries of the oil-bearing area the static head of water is high, which clearly indicates the absence of water movement.

It should be noted that the two major reasons for this absence of water movement are:

1. The oil of Artem Island is the most viscous of all the Baku oils. Moreover, toward the oil-water contact point a sharp increase of specific gravity and therefore an increase in viscosity are noted. Oil from well No 407, located close to the boundary of the oil-bearing area, had specific gravity of 0.940, while 0.910-0.915 was the average for the whole deposit. This well is also remarkable in that, although it was near the boundary of the oil-bearing area, contour water did not reach the well.

2. It must be assumed that oil viscosity alone did not prevent the water from moving in the bed. Another factor preventing water movement is the low permeability of sand in the bordering area. This is due to hard mineral particles, mostly of calcium carbonate which are formed by the chemical interation of oil, water and gas, and which fill the sand pores.

These two factors, occasioning resistance to water movement and a considerable decrease of the permeability of sands, which in some cases may result in a complete obstruction of pores, may provide the main explanation for the stability of the water limit, in addition to the considerable difference in bed pressures between the oil-bearing and water-bearing portions.

Therefore, in beds where there is no movement of contour water trans-contour flooding can bring no positive results.

In this kind of bed we suggest artifically creating conditions which are appropriate for the hydraulic conditions already obtaining. No flooding should be conducted in the area outside the oil bed. Excluding the zone located near the water-oil contact line, where oil viscosity is high and permeability of sand is low, flooding should be conducted through injection wells located within the oil-bearing area along the edge of the depression zone where permeability of the sand is good.

Such an operation does not impair the process of exploitation of the whole deposit.

The KK formation of Artem Island represents a most appropriate site for contour flooding. Since the western limit is in the sea, it is easier and more expedient to start the flooding on the eastern side, selecting for this purpose a series of oil wells (No 264 and 314) stretching along the beds in a line parallel to the contour of the oil-bearing area.

Later, it will be possible to expand the line of the injection wells to the north and to the west, disposing them along the line of the main tectonic disturbances, which is also the southern limit of the oil-bearing strata.

Physicochemical Properties of Water Used for Flooding

The successful application of flooding depends largely on the physico-chemical properties of the water used. In recent years, in AzNII (Baryshev, Malyshev, Gorin, etc.) the capacity of different kinds of water for flushing collecting sands were studied. Special attention was paid to alkaline and sea waters. Experiments showed that when alkaline water is used to force the oil out of the collectors of a productive layer, the output is 13 percent greater than with hard water.

50X1-HUM

Table 3 shows data on separate experiments:

Table 3

Horizon	Final Coefficient of Yield: With Alkaline Water	Final Coefficient of Yield: With Hard Water	Difference Between Coefficients of Yield With Alkaline and Hard Water	Note:
IV Liter (Bostanar-Shor)	66.4	56.8	9.6	Sea water
PK of Artem Island	75.4	62.5	13.1 [sic]	was used
PK_1 of the Kirmakin Valley	70.6	55.8	14.8	as hard water

Therefore, when sea water is used, results are as inefficient as when using the bed hard water. Experiments with sands, approximating the ideal granulometric composition, showed supplementary yield amounting to 5.1-5.6 percent of the oil initially contained by the collectors, when sands flooded by hard water were flooded subsequently by an alkaline water solution.

Moreover, it has been established that the speed of the water through the sands is of great importance. Experiments with a cylinder filled with oil-saturated sand and subjected to an alkaline water action show that the average speed of the anhydrous oil's outflow is 1.4 greater than the speed when hard water is used. In other words, in a given period of time alkaline water would force out 1.4 times more oil than hard water. Experiments also show, when flooding oil-bearing collectors with no water affinity, alkaline water is to be used exclusively.

When the working agent in flood operations is decided upon, the properties of water used for flooding must be similar to the properties of water in the bed. The mixing of these waters in the layer should not cause a chemical reaction, which is usually accompanied by precipitation and by a decrease of the collectors' permeability. If there is no possibility of determining the similarity of chemical composition for both bed water and the water used for flooding, the guiding principle is to use waters belonging to the same type, i.e., to flood with hard water beds containing hard water, and to use only alkaline water.

Utilization of sea water is a rather special problem. Great amounts of sea water are used for technical purposes in the industry, and every well may be furnished with an unlimited supply. The unlimited resources and the low cost of this water make it tempting to use it as a working agent for flooding.

However, some considerations necessitate dealing very carefully with the possibility of using it on an industrial scale.

1. Since a simple mixing of sea water and alkaline water at the surface causes precipitation, pumping of sea water into alkaline water in the earth's depth must be assumed to lead to a chemical reaction and to the obstruction of pores by the resulting precipitate.

50X1-HUM

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2. According to the above-mentioned experiments made by the AzNII, the flushing capacity of sea water is far below that of alkaline water. Therefore, it would be a mistake to use sea water as an operating agent.

3. There have been many examples in the oil industry showing negative results obtained from using sea water in the exploitation of wells. When wells are drilled, or obstructing sands are flushed off, various measures providing for the replacement of the oil by sea water or alkaline water are usually undertaken to avoid any undesirable consequence from sea water infiltrating into the oil bed.

However, the extensive network of pipe lines for sea water supply and the unlimited quantities of sea water available throughout the industrial area make it compulsory to carry on research and to call for specialists in physics and chemistry to determine precisely whether or not sea water may be used for injection into oil beds.

Determining the Amount of Residual Oil

The physical factors describing the layer and, in particular, the coefficient of residual oil saturation are of considerable importance. The evaluation of the percentage of underground water gives an approximation of this coefficient but does not resolve the problem entirely, because the calculation of the coefficient of saturation from data on total oil reserve and on amounts of oil and gas already extracted may be subject to great errors. Our national machine-manufacturing plants must organize the production of special core drills, assuming that we have advanced to where we can gather core samples to study the conditions in the bed.

Some special aspects of secondary recovery methods were studied above.

However, technical and organizational problems, on which depends the success of the enterprise, must be faced and solved now. The starting point of this part of the business must be the work which was planned by decision of the TsKKP (b) of Azerbaydzhan and defined in the Special Order of the Minister of Oil Industry in the southern and western regions of the USSR. (Order No 309, 1 July 1947, "On the Introduction of Secondary Recovery Methods for the Exploitation of Oil Deposits.")

The application of secondary recovery methods is planned for 1948 in a considerable number of wells (30 percent) in the Azneft' combine. This requires a special organization for obtaining, collecting and transporting water, for the construction of water-purification plants, for building air lines to the injection wells, etc.

The present condition of wells in the separate beds requires a great amount of work. New wells must be drilled to provide for injection, and to reorganize the oil-well network.

Therefore the problem of drilling is equally important and has to be specially organized.

The success of operations to be faced in 1948 depends greatly on a timely solution of the problems examined here.

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